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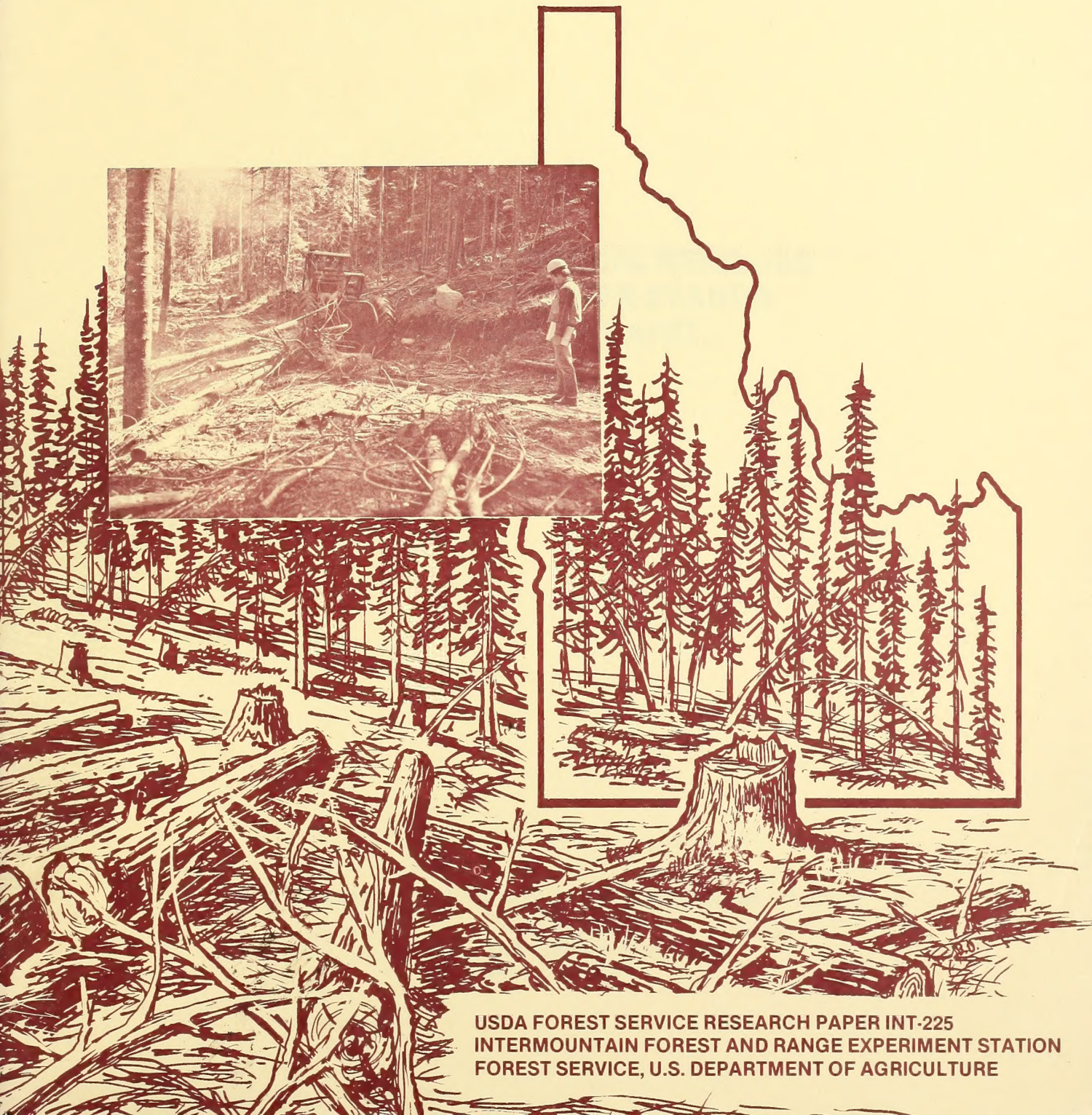
A. L. CHASE



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SALVAGING LOGGING RESIDUES IN MIXED-CONIFER STANDS OF NORTH IDAHO

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RESEARCH SUMMARY

Two timber sales in north Idaho were experimentally relogged to determine if residues could be reduced through imposition of strict wood utilization standards. Relogging took place in 1975, one year following the initial logging. The 57-acre (23.1-ha) Danby Ridge sale, which had never been logged before, had an overstory of mixed sawtimber of medium stocking, 160 years old, and an understory of mixed polesize material of poor stocking, 80 years old. The 23-acre (9.3-ha) Lee Creek sale, which had been logged for cedar in the 1950's, had an overstory of mixed, 100-year-old sawtimber of medium stocking, with an understory of 60-year-old, poorly stocked, mixed polesize material.

The initial logging removed only green sawlogs 8 feet (2.44 m) long to a 10-inch (25.4-cm) top, or 10 feet (3.05 m) long to an 8-inch (20.32-cm) top, containing a minimum of 10 board feet (3 ft^3) and more than one-third sound. On Danby Ridge, about 15.7 thousand board feet per acre was harvested; about 6.7 thousand board feet per acre remained as dead and green residue; and about 0.1 thousand board feet per acre remained as residual timber. Volumes on Lee Creek were 9.8 thousand board feet harvested. 6.5 thousand board feet residue, and 2.5 thousand board feet residual timber.

On a 5-acre study plot, post-harvest residues 3 inches (7.62 cm) in diameter and larger amounted to 8,940 cubic feet (253 m^3) on Danby Ridge and 8,978 cubic feet (255 m^3) on Lee Creek. Relogging to recover material suitable for pulp, shake bolts, fence posts, and sawlogs with a 4-inch (10.16-cm) top, resulted in recovery of 5,291 cubic feet (150 m^3) on Danby Ridge, a residue reduction of 59 percent. An additional 3,931 cubic feet (113 m^3) was harvested on Lee Creek, a residue reduction of 44 percent.

On Danby Ridge, most of the salvage was suitable only for pulp, whereas on Lee Creek many pieces qualified for other products. Salvaged wood was skidded to the roadside but none was actually sold because the market for such materials softened as the study was nearing completion.

Production rates were measured for two harvesting machines common to north Idaho--a Caterpillar D2 tractor and a John Deere 540 rubber-tired skidder. On Danby Ridge, the tractor skidded 623 pieces (6,026 ft^3) (168.7 m^3) an average one-way distance of 70 feet (21.34 m) in 44 hours. On Lee Creek, the skidder moved 625 pieces (3,062 ft^3) (85.7 m^3) an average 204 feet (62.18 m) in 22 hours. Because of larger piece size on Danby Ridge, the two machines moved about the same volume of wood per hour.

The skidder operated at below payload capacity because residues were in small pieces. The tractor, although working close to capacity, was impeded by not having a winch. Until special harvesting equipment designed to handle residues is available, the small, multi-purpose skidder will remain the most practical machine for salvage logging.

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INTRODUCTION

The forester of today must increase the supply of wood fiber from a shrinking timberland base while minimizing environmental damage, aesthetic disturbances, and fire hazards. One important method for accomplishing these objectives is to utilize more of the residue resulting from treatments of mature stands.

Although forest industries in the Northern Rockies are obtaining an increasing amount of raw wood from residues formerly abandoned or burned, volumes and characterists of this material and prospects for additional wood utlization are largely unknown in mixed conifer types of north Idaho. Little quantitative data is available on the efforts expended and results of adopting stringent utilization standards.

This report describes experimental relogging of two State of Idaho (Department of Lands) timber sales in the mixed-conifer type of north Idaho. The relogging was conducted in July and August of 1975. Both sales had been conventionally harvested within one year of the relogging. The study was intended to answer the following questions:

1. What are the volume and characteristics of logging residue after conventional logging?

2. What additional products and wood volumes could be removed in a relogging operation imposing stringent utilization standards?

3. What are the residue volumes and characteristics after relogging?

4. What relogging production rates might be expected using equipment common to north Idaho?

The study revealed that logging residues can be reduced approximately 40 to 60 percent in cubic volume, and significant quantities of useable raw wood can be recovered by imposing logging standards more stringent than normal. Relogging production rates were dependent on machine condition, capacity, and flexibility as well as site conditions and residue characteristics. Economic feasibility of relogging which depends upon the prevailing market for small logs and pulp bolts, was beyond the scope of this study.

THE STUDY AREAS

Selection of Study Areas

During the spring of 1975, six recently logged areas representing the mature, mixed-timber types of north Idaho were selected for preliminary residue measurments. A cutting block on each sale was transect-inventoried to determine residue character and volume. Comparison of timber sale statistics and transect survey results provided the basis for estimating amounts of wood harvested and residues. The range of stand conditions utilization standards, and residue amounts are presented in appendixes I and II to allow the interested reader to make generalizations concerning his own situation. The following criteria were used to select the study areas.

1. Utilization standards of sale and logging methods

2. Silvicultural treatment

3. Sale volume per acre

4. Age of timber cut and remaining timber

5. Species mixture on area

6. Availability of sale records

7. Degree to which residues represented post-logging conditions

Study Area Descriptions

The Danby Ridge sale near Rathdrum and the Lee Creek sale, east of Priest Lake, were selected for study on the basis of similarities and differences, as follows:

1. Similarities

   Terrain in both cases was gentle--10 to 15 percent.

   Only sawlogs were removed in the harvesting.

   Utilization standards were very similar.

   Both areas were harvested with small-to medium-sized mobile skidders.

   Access was excellent on both sales. Two or more sides were roaded.

   Sales records were good.

   Residue had been on the site for one year or less.

   The following stand descriptive criteria were in effect at the time of the conventional harvest. Sawtimber was 11.0 inches (27.94 cm) d.b.h. and larger; polesize was 5.0 to 10.99 inches (12.7 to 27.92 cm) d.b.h.; medium-stocked was 76 to 149 square feet (7.06 to 13.84 m^2) of net basal area per acre, or 40 to 70 percent by crown closure; poorly stocked was 20 to 57 square feet (1.86 to 5.30 m^2) of net basal area per acre, or 10 to 40 percent by crown closure.

2. Differences

   A seed tree cut of Danby Ridge removed 160-year-old stems and most of the volume (fig. 1). In contrast, a commercial thinning removed 100-year-old stems and about 80 percent of the volume of Lee Creek (fig. 2).

   The Danby Ridge sale, situated on a ridgetop exposed to frequent high winds and thunderstorms, had a high percentage of cull and broken-top trees (fig. 1). In fact, the seed tree cut actually turned out to be a clearcut, with scattered reproduction and 60- to 80-year-old poles. Lee Creek, located in a draw and bordered by a creek, was a healthy stand before and after harvesting.

   Danby Ridge had no history of past logging on the study site, although parts of the surrounding sale area had been previously harvested. Lee Creek had been cut for cedar products in the 1950's. Most of the dead, rotten pieces came from this operation.

   Prior to harvesting, the timber overstory on Danby Ridge consisted of mixed sawtimber, medium-stocked, 160 years old. The understory was mixed polesize material, poorly stocked, 80 years old. Overstory on Lee Creek was mixed sawtimber, medium-stocked, 100 years old. Understory vegetation was composed of mixed polesize material, poorly stocked, 60 years old.

Figure 1.--Danby Ridge sale after harvesting.

Figure 2.--Lee Creek sale after harvesting.

STUDY METHODS

Inventory Procedures

A 5-acre (2.02-ha) rectangular block on each of the two sites was laid out and all residue more than 8 feet (2.44 m) in length and 3 inches (7.62 cm) in diameter (small end) was measured. Original wood volume on the two study sites and the progressive effects of each treatment on residue amount and character were compared. Conventional logging was measured in board feet, relogging in cubic feet. Much of the residue remaining after logging was too small to be expressed in board feet. Only residue 3 inches (7.62 cm) or more in diameter was measured on the 5-acre (2.02-ha) study areas; residue smaller in diameter was deemed useless. A board foot: cubic foot ratio was computed for comparing the two measurements of volume.

Relogging Production Procedures

Two methods of skidding were compared on a round-trip basis. Miscellaneous production and nonproduction time was also analyzed. Skidding was timed with a stop watch and the turn pieces and volumes tallied.

CONVENTIONAL LOGGING

Utilization Standards and Products

Sawlogs.--Only green sawlogs (8 feet [2.44 m] long to a 10-inch [25.4-cm] top, or 10 feet [3.05 m] long to an 8-inch [20.32-cm] top) containing a minimum of 10 board feet (3 ft^3) and more than one-third sound were considered merchantable and were removed from both study areas. "One-third sound" meant that a piece containing a gross scale of 30 board feet must have 10 sound board feet to be merchantable. Rot, sweep, crook and checks were considered defects. Summation of cubic volume contained in residue pieces grossing 10 board feet revealed that an average 10-board-foot piece contained approximately 3 cubic feet.

Pulpwood.--Although no pulpwood was removed, Department of Lands pulp standards were hypothetically applied to determine how removal of this additional product would have affected residue volumes.

Pulpwood is defined as green or dead softwoods not merchantable for sawlogs but containing 10 board feet of pulpable material, and having one-third or more of the gross volume in sound wood.

Rot-infected wood is considered merchantable for pulpwood if the wood fibers cannot be extracted from the end of the log with the fingers. Logs having an unmerchant-

able core greater than the maximum allowable size listed in table 11 of A Manual of Instruction for Log Scaling and the Measurement of Timber Products (State of Idaho VO-ED No. 38) are not considered merchantable. Checks, splits, crook, and blue stain are not considered as defects in determining pulpwood volume.

Pre-Harvest Inventory

The pre-harvest inventory was found by adding green and dead pieces containing 10 or more gross board feet to the volume of the residual stand and scaled logs removed. Table 1 shows the pre-harvest volumes.

Table 1--*Preharvest volumes on north Idaho timber sales*

Sale name	Sale size	Volumes per acre				
		Removed	Residual[1]	Green Residue	Dead Residue	Total
	Acres	*Thousand board feet*				
Danby Ridge	57.0	15.7	0.1	2.8	3.9	22.5
Lee Creek	23.0	9.8	2.5	1.7	4.8	18.8

[1] Includes trees that blew down following logging.

Post-Harvest Inventory

Board foot and cubic residue volumes (pieces 8 feet [2.44 m] and longer and 3 inches [7.62 cm] and more in diameter) left after conventional logging are shown in table 2. Principle findings are:

1. Dead residue made up most of the gross volume on both study areas; however, green pieces were more abundant in both instances.

2. Rot was rather evenly spread between green and dead material on Danby Ridge regardless of piece volume. Large pieces, both dead and green, contained a high percentage of cull material on Lee Creek. Small pieces (less than 3 cubic feet) were generally defect free.

3. Useable (net) residue pieces on Danby Ridge were larger and less numerous than those on Lee Creek.

Because conventional methods of board-foot measure disregard pieces with end diameters less than 6 inches (15.24 cm), cubic volume provides a much better measure of total volumes than board-foot volume. However, a board foot:cubic foot ratio was desired to allow referral to the Pre-Harvest Inventory (table 1) and permit further categorization of the residue occurring on the two sites. Because this ratio is greatly influenced by piece size, a general ratio to cover the range of diameters was needed. On Lee Creek, dead residue (material dead before initial harvesting) was larger than

the green residue (created in the harvesting). Residue condition was then used to obtain board foot:cubic foot ratios for pieces containing 10 board feet (3 ft^3) or more, as follows: Lee Creek, dead residue, 5.78-1; green residue, 4.68-1; Danby Ridge, dead residue, 4.96-1; green residue, 5.01-1.

Table 2.--*Post harvest inventory (5 acres), number of pieces and gross volumes*

Item	Danby Ridge			Lee Creek		
	Pieces	*Ft^3*	*M bd.ft.*	*Pieces*	*Ft^3*	*M bd.ft.*
Dead residue	325	3,674	19.34	266	4,262	23.91
Green residue	377	2,996	13.65	591	2,482	8.53
Green blowdown	5	71	.41	85	838	4.04
Total	707	6,741 (190.74 m^3)	33.40	942	7,582 (214.57 m^3)	36.48
Pieces in total less than 1/3 sound	136	1,438	7.74	156	3,732	22.03
Pieces in total less than 3 ft^3	152	270	--	422	640	--
	Number of pieces and net (pulpwood base) volumes[1]					
Dead residue	208	2,472	12.70	122	941	5.80
Green residue	358	2,800	12.56	580	2,370	5.81
Green blowdown	5	31	.41	84	539	3.24
Total	571	5,303 (150.08 m^3)	25.67	786	3,850 (108.95 m^3)	14.85
Pieces in total less than 3 ft^3	136	236	--	399	607	--
Pieces in total less than 10 bd. ft.	152	--	--	399	--	--

[1]Includes pieces averaging 27% solid rot and 12% sound defect on Danby Ridge and 10% solid rot, 4.5% sound defect on Lee Creek.

RELOGGING

Utilization Standards and Products

Although utilization standards were more stringent than normal, an attempt was made to recover products merchantable at the time of the study and in the future. Discussion with those knowledgeable about buying and selling wood products led to the following products and standards.

Sawlogs.--Minimum length, 8 feet 6 inches (2.59 m); minimum top diameter inside bark, 4 inches (10.16 cm). All sawlogs cut in multiples of 8 feet (2.44 m). No sweep, splits, checks, or rot that would lessen the volume within these minimum dimensions. Specifications applied to coniferous species both green and dead.

Pulpbolts.--Minimum length, 8 feet (2.44 m); minimum top diameter inside bark, 3 inches (7.62 cm). In effect, one third or more sound and containing at least 0.4 cubic feet of useable wood fiber. All species, both hard and soft wood, green or dead, with the exception of western red cedar were considered for pulpwood. Pieces containing less than one-third sound wood by volume were not considered merchantable because they would likely disintegrate during handling. Large logs with crumbly rotten heartwood and solid shells were made into products using table 11 (VO-ED No. 38) as a guide.

Posts.--Lodgepole pine, western Larch, Douglas-fir, and western red cedar were considered merchantable for posts. Utilization standards were identical to sawlogs, except 7 feet (2.13 m) was the minimum length and 3 inches (7.62 cm) the diameter of the small end.

Shake and shingle bolts.-- Western red cedar was the only species considered for these products. All cedar more than one-third sound, at least 6 feet (1.83 m) long, at least 12 inches (30.48 cm) at the small end, and capable of squaring out sound 4-inch (10.16 cm) pieces was considered.

Pre-Relogging Inventory

As mentioned in the post-harvest inventory section, all residue was measured and counted. To evaluate the volume, utilization potential, and characteristics of the residue, the following information was recorded:

1. Type of residue--green (created in logging) or dead
2. Diameter at large end and small end, plus length to obtain volume; the formula for a uniformly tapered cylinder and a constant of 0.001818 was used to determine cubic foot volumes
3. Species of piece
4. Percentage of rot and sound defects that would lessen potential product recovery
5. Number of sawlogs, poles, posts, pulp bolts or cedar products that might be recovered.

All pieces to be skidded were marked with paint. At Danby Ridge, pieces that were likely to break up in recovery (less than one-third sound) were marked with a separate color and separated on the landing. Pieces likely to fall apart in relogging were not marked or skidded on Lee Creek. More will be mentioned about these pieces later.

The number of potential products made on site from useable pieces are shown in table 3. The table reveals that few products were made from pieces containing less than 10 board feet (3 ft^3) on Danby Ridge; this was not the case on Lee Creek. Green residue provided the source for most of the sawlogs on both areas. About 18 percent of the sawlogs on Danby Ridge were obtained from green blowdown material, resulting after the harvesting was completed. Forty-seven percent of the relogging sawlogs were obtained in this manner on Lee Creek. Pulpwood constituted the majority of relogging products in both cases, although the size of the material varied greatly between sites. Sixteen percent of the pulpbolts were made from pieces containing less than 3 cubic feet on Danby Ridge, while this material made up 47 percent of the pulp at Lee Creek. About 1.7 products were made from each piece of merchantable residue on Danby Ridge and 2.3 products on Lee Creek.

Table 3.--*Pre-relogging inventory (5 acres), potential products marked on site*

Product	Danby Ridge	Lee Creek
	No. of products	No. of products
Sawlogs:[1]		
Dead	5	42
Green	55	147
Green blowdown	12	132
Pulpbolts:[1]		
Dead	410	271
Green	513	907
Green blowdown	5	194
Posts:[1]		
Dead	--	1
Green	--	69
Shakebolts:[1]		
Dead	--	29
Green	--	18
Total products	995	1,810
Total pieces	707	942
Total useable pieces	571	786
Products in total that were made from pieces less than 10 bd.ft. or 3 ft^3	152	688

[1] See specifications in relogging: Utilization Standards and Products.

Post-Relogging Inventory

After completion of the relogging, each area was inventoried to determine the cubic volume of all pieces 3 inches (7.62 cm) or more in diameter and 1 foot (0.3 m) or more in length. Table 4 shows the results of this inventory. Pieces longer than 8 feet (2.44 m) are included. This is due to one of three causes: too rotten to make products, missed in the relogging, broken and abandoned. As mentioned before, pieces less than one-third sound were considered too rotten to move and stay together. This hypothesis was tested on Danby Ridge. These pieces were marked with blue paint and the operator conducting the relogging was asked to attempt skidding them; 70 pieces out of 136 broke up in the skidding operation. On Lee Creek, 156 rotten, no product pieces were left in place because of the anticipated breakup.

Table 4.--*Post relogging inventory (5 acres) residue 3 inch diameter or larger*

Study phase	Danby Ridge		Lee Creek	
	Pieces	*Ft³*	*Pieces*	*Ft³*
Residue volumes and pieces before relogging:				
Longer than 8 ft	707	6,471	942	7,582
Shorter than 8 ft	1,110	2,199	1,434	1,396
Total	1,817	8,940 (253 m^3)	2,376	8,978 (254 m^3)
Residue volumes and pieces after relogging:				
Longer than 8 ft	136[1]	1,438	156	3,433
Longer then 8 ft but missed or broken	5	12	80	218
Shorter than 8 ft	1,110	2,199	1,434	1,396
Total	1,251	3,649 (103 m^3)	1,670	5,047 (143 m^3)
Percent reduction	31.2	59.2	29.7	43.8

[1]66 pieces (641 ft^3) skidded and decked separately; 70 pieces left on site; see post-relogging inventory for details.

Residue Reduction

One of the objectives of the study was to evaluate additional residue reduction achieved by relogging. Post-harvest residues 3 inches (7.62 cm) in diameter or longer amounted to 8,940 cubic feet (253 m^3) on Danby Ridge and 8,978 cubic feet (255 m^3) on Lee Creek. Relogging resulted in removal of 5,291 cubic feet (150 m^3) on Danby Ridge, a reduction of 59 percent. An additional 3,931 cubic feet (113 m^3) was removed in relogging Lee Creek, a reduction of 44 percent. A per-acre approximation of the cubic volumes existing prior to each treatment is shown in table 5. Pre-harvest volumes were found by applying a board foot:cubic foot ratio of 5 to 1 to the total of table 1. Post-harvest and post-relogging volumes were obtained from table 4.

Residue conditions following relogging on both study areas are shown in figure 3 (Danby Ridge) and figure 4 (Lee Creek).

Table 5.--*Gross residue volumes per acre for major phases of study*

Study phase	Danby Ridge	Lee Creek
	Cubic feet	*Cubic feet*
Preharvest	4,500	3,760
Harvesting:		
Post harvest	1,788	1,805
Residual	20	500
Total	1,808 (51 m^3)	2,305 (65 m^3)
Relogging:		
Post relogging	730	1,009
Residual	20	500
Total	750 (22 m^3)	1,509 (43 m^3)

Figure 3.--Danby Ridge sale following relogging.

Figure 4.--Lee Creek sale following relogging.

Product Recovery

The decked material could not be sold when the pulp market weakened throughout the Northwest about the time the study was concluded. Total merchantable products and cubic volumes are based on roadside-decked pieces. The figures in table 6 were derived by subtracting the post-relogging inventory from the post-harvest inventory. This method was followed because (1) only cubic volumes were measured during the relogging, (2) not all pieces were measured, and (3) some rotten pieces were left on Danby Ridge, and others were skidded. On Lee Creek, a number of sound pieces were broken or missed and were deducted from the total number of products recovered.

Table 6.--Number of products recovered (5 acres), as marked and decked.

Product	Danby Ridge		Lee Creek	
	Marked	Decked	Marked	Decked
	Pieces			
Sawlogs	72	72	321	321
Pulpbolts	928	921	1,372	1,219
Posts	--	--	70	69
Shake and shingle bolts	--	--	47	47
Total	1,000	993	1,810	1,656

Production Analysis

A principal objective of this study was to compare relogging production rates, using equipment common to north Idaho. Both the logger and the landowner must have incentives to remove and utilize residues. One real incentive is removing enough additional wood to pay for the cost of relogging. Value cannot be estimated unless the time required to harvest products or wood fiber is known. Production rates are known for logging equipment in the major timber types of north Idaho. The operator usually compares his equipment to these norms; given volume, distance of skid, and other operating conditions, he establishes his own production rate and costs.

Relogging production rates are not known; thus a logger has no comparative data from which to establish his own production rate and cost. The following analysis (tables 7 and 8), although limited to two stands and two skidding systems, should provide a basis for comparison.

Table 7.--*Relogging production data: actual work day vs. 8-hour day*

Item	Danby Ridge	Lee Creek
Number of pieces	307	471
Number of days	5	2
Number of pieces per day	61	235
Number of pieces per 8-hr day	104	259
Average length of piece.....feet..	17.0	23.1
Average small-end diameter.....inch..	8.5	4.1
Volume.....cubic feet..	3520	1980
Volume per day.....cubic feet..	704	990
Volume per 8-hr day.....cubic feet..	1220	1095
Number of turns	127	76
Number of turns per day	25.4	38
Number of turns per 8-hr day	44	42
Production time per day.....hours..	3.8	6.6
Production time per 8-hr day.....hours..	6.6	7.2
Non-production time per day.....hours..	0.8	0.7
Non-production time per 8-hr day..hours..	1.4	0.8

Table 8.--*Relogging production: average times and distances by turn*

Parameter	Danby Ridge	Lee Creek
Production elements:		
Time out..(all times in minutes)..	0.9	1.6
Hook time	2.3	3.9
Bunch time	1.8	1.0
Time in	0.9	1.1
Unhook time	1.1	1.0
Landing time	0.9	1.0
Round-trip time	7.9	9.6
Misc. production time	1.1	0.6
Non-production elements:		
Personnel not working	0.4	1.1
Machine down time	1.5	0.1
One-way distance.....feet..	70	204
Number of pieces	2.4	6.2
Volume.....cubic feet..	27.72	26.09

Skidding methods and equipment.--Two conventional mobile skidding methods were compared: a crawler tractor (Danby Ridge) and a rubber-tired skidder (Lee Creek).

1. Crawler tractor (fig. 5). The crawler tractor evaluated was an old Caterpillar Model D2, a machine used for light-duty construction, forestry, and farming. Skidding was accomplished by placing two or three chokers over a drawbar pin. Usual skidding procedure was to drag one to three logs to the edge of the long axis of the area. Because the tractor lacked a blade, little bunching of the logs was possible. The operator was instructed to skid all sound pieces and to attempt to skid unsound pieces. Machine down time was common. A total of 9 full and partial days were required to complete the skidding of the 5-acre (2.02-ha) tract.

Figure 5.--Relogging Danby Ridge with small crawler tractor.

2. Rubber-tired skidder (fig. 6). A medium-sized, rubber-tired skidder was selected to represent a type of machine commonly used in north Idaho. This unit was a John Deere Model 540 equipped with a winch and five to seven chokers. In practice, five to seven logs were skidded to one of three landings. (The blade of the skidder was used to deck the pieces 6 to 8 feet (2 to 3 m) high. The operator was free to skid as he wished, provided that all marked pieces were removed. No machine down time other than fueling was noted for this operator. Two full days and 1 partial day were required to skid the 5-acre (2.02-ha) area. In both instances, the wood recovered was not sold to the logger.

Timed observations.--Two people observed production on each study area. One individual, positioned at the landing, recorded number of turns and pieces and measured length and diameter on all pieces. The second person followed the turn of logs from the woods to the landing. All elements of the operation were timed with a stop watch to the nearest hundreth of a minute. Elapsed time for each event was noted, then the watch was kept running. This method allowed for a slight error when compared to total operating time (about 2 to 3 percent short). Unusual delays in production were noted. Because the crew members were in frequent contact, number of pieces per turn, turn number, and gross time could be compared.

Figure 6.--Relogging Lee Creek with rubber-tired skidder.

Because the skidding systems were investigated under different stand and operating conditions, total skidding time was broken into minor elements to facilitate comparative analysis of the data. Production elements directly related to output per turn (skidding) were added to obtain round-trip time. Breaks in the round-trip time were classified as productive and nonproductive delays. Productive delays include items such as hang-ups, straightening out chokers, and moving stumps. Nonproductive delays include operator breaks, machine down time, and operator discussion with the study team. Because of scheduling problems and the demands of other work necessary to complete the study, only a portion of the actual production process was timed on each area. Lee Creek was timed 2 days out of the 3 production days. Danby Ridge was timed 5 days out of 9 days. In both instances, the operator kept track of total hours worked, total number of turns, and pieces when the study team was absent. The results of measured total production variables can be seen in table 7.

The most important production activity for which data was gathered was roundtrip skidding time composed of six elements:

1. Out-time. Time required to move the skidding unit from the landing to the general area where the logs are to be hooked. Out-time starts when the skidder leaves the landing and stops when the machine arrives at the hooking site.

2. Hook-time. Time required to get a choker around a log. Hook-time starts when the operator gets off the skidder. It ends as he returns to his machine.

3. Bunch-time. Time required for lateral movement of one or more logs prior to moving towards the landing with a turn. It also includes the time necessary to break pieces loose from their initial resting place and place them where they can be reassembled. Bunch-time started as the machine or winch started to apply pressure to the choked log. It ended when the piece was lined up to start for the landing.

4. In-time. Time required for the skidding unit to move individual pieces, and the turn towards the landing. In-time started when a piece was started towards the landing. It ended when the load was deposited on the landing and the machine stopped.

5. Unhook-time. The time required to unhook the turn and drag the chokers free. Unhook-time started when the operator stopped on the landing and ended when the chokers were in position for the trip out and the operator was back on his machine.

6. Landing-time. Includes all time on the landing other than out-time, in-time, or unhook-time. Landing-time started when one of these three activities ceased and stopped when they were resumed.

A summary of average production elements by turn is shown in table 8. These averages are delay free. The effect of delays may be found by adding miscellaneous down time, machine down time, and operator time out to round trip time.

Production findings.--Tables 7 and 8 prove the value of using equipment designed and built specifically for moving small pieces of wood. Neither the tractor nor the rubber-tired skidder operated as efficiently as stand condition, piece size, and time would indicate. This conclusion is based on the following observations:

1. Poor tractor maintenance contributed to short work days.

2. Lack of a winch required excessive bunching time.

3. The tractor was much slower than the skidder. The average one-way skid was only one-third as far, but required 75 percent of the time taken by the skidder. Difference in skidding distance on two areas of similar configuration and size was due to the rubber-tired skidder making only three decks and the tractor stringing out the turns along both long axes of the area.

4. Due to larger residue size and a shorter one-way skid on Danby Ridge, the tractor moved approximately the same cubic foot volume per hour as the rubber-tired skidder moved on Lee Creek.

5. The skidder was worked far below capacity. The operator was unable to add enough chokers to work his machine efficiently. The tractor worked at or near capacity much of the time.

6. Because of its size the skidder crushed and broke more material than the small tractor broke at Danby Ridge.

Regression analysis.--Regression equations of the form $Y = b_0+b_1X$ were calculated for each of the independent variables thought to influence some dependent production element. The t-statistic was used to test the hypothesis that a linear relationship exists between the two variables considered. All tests were done at the 95 percent confidence level. A linear relationship was shown to exist in many cases. Looking at the R^2 value makes production variation more meaningful. R^2 indicates the proportion of variation in Y explained by X. For example, an average of 40 percent of the variation in time out (table 9) is explained by distance. The results for other production elements are shown in table 9.

Table 9.--*Relogging production regression coefficients*

Y	X	Danby Ridge				Lee Creek			
		b_0	b_1	R^2	t-test	b_0	b_1	R^2	t-test
Time out	dist.	0.38	0.007	0.38	*	0.63	0.005	0.42	*
Time in	dist.	.59	.005	.21	*	.33	.004	.43	*
Time in	turn vol.	.65	.01	.14	*	.94	.005	.009	
Time in	no. logs	.88	.02	.001		.64	.07	.03	
Hook time	no. logs	1.22	.46	.14	*	1.58	.37	.17	*
Bunch time	no. logs	.08	.71	.33	*	.87	.03	.006	
Unhook time	no. logs	.50	.27	.13	*	.54	.07	.07	*
RT time	no. logs	5.64	.99	.08	*	5.87	.60	.16	*
RT time	turn vol.	7.34	.03	.02	*	9.16	.015	.006	

$Y = b_0+b_1X$

*Indicates that on the basis of the data, a linear relationship exists between the two variables (t-test done at the 95 percent level).

DISCUSSION AND CONCLUSIONS

The data presented indicate the volumes and characteristics of logging residue left in north Idaho's mixed conifer stands following sawlog removal. By conventional sawlog standards, little merchantable residue remained on either site after logging. However, the material that was left offered real, although varying possibilities for additional product recovery and residue reduction. The study produced the following conclusions:

1. Residues left on site after conventional sawlog harvesting vary in defect, condition class, and individual size (table 2).

2. Initial harvesting of other products may reduce the need for relogging. Removing pulpwood of conventional standards would have left few useable residues on Danby Ridge (table 3). Conventional removal of pulp on Lee Creek would have left numerous small pieces of potentially useable residue.

3. Stringent utilization standards resulted in 993 products (mostly pulpwood) and 5,291 net cubic feet of wood fiber being removed in relogging Danby Ridge (tables 4 and 6). Some 1,656 products and 3,821 net cubic feet were removed on Lee Creek.

4. A cubic foot volume comparison of post-sale residue and post-relogging residue larger than 3 inches (7.62 cm) in diameter showed a 59 percent reduction on one area and a 44 percent reduction on the other.

Although further study is needed to determine the most efficient equipment for relogging, the following factors strongly influence production rates:

1. As with conventional harvesting, machine capacity and design must be matched with wood size and character. The value of equipment that matches residue conditions is best shown by the total relogging effort on the study areas. The tractor on Danby Ridge required 44 hours to skid 632 pieces (6,026 ft^3 [171 m^3]) an average one-way distance of 70 feet (21.34 m). The rubber-tired skidder needed only 22 hours to skid 625 pieces (3,062 ft^3 [87 m^3]) an average one-way distance of 204 feet (62.18 m). However, due to the larger piece size on Danby Ridge, on a per-hour basis approximately the same cubic volume was skidded on both areas.

2. Machines designed for conventional harvesting operate far below volume capacity on relogging sites where numerous small pieces of wood fiber must be recovered.

3. Until equipment designed for relogging is readily available, cheap multipurpose equipment appears to offer the most practical means for relogging.

APPENDIX I

Table 10.--*Pre-survey timber sale statistics*

Sale name	Area size	Avg. slope	Cruise volume	Scaled volume Removed	Silvicultural treatment	Logging method	Utilization standards: Minimum d.b.h.	Minimum log length	Size top	Cull in log
	Acre	*pct.*	------*M bd.ft/acre*------				*inch*	*foot*	*inch*	*pct.*
CHILCO Mixed sawtimber, poorly stocked, 75 yrs. over mixed polesize, well-stocked, 50 yrs.	9.6	20	16.4 No pulp incl.	8.0 Pulp not removed	Intermediate thinning	Chainsaw felling & small crawler tractor skidding (D-4)	4	8.25	3.5	66-2/3
LEE CREEK Mixed sawtimber, medium stocked, 100 yrs. over mixed polesize poorly stocked, 60 yrs.	23.0	15	10.0 No pulp incl.	9.8 Pulp not removed	Marked-to-cut selection (commercial thinning)	Chainsaw felling & small crawler tractor skidding (JD-450)	9	8.25 10.25 12.25	10. 8. 6.	66-2/3
DANBY RIDGE Mixed sawtimber, medium stocked, 160 yrs., over mixed polesize poorly stocked, 80 yrs.	27.0	13	17.2 No pulp incl.	15.7 Pulp not removed	Marked-to-leave seed trees	Tree length, chain saw felling & medium rubber-tired skidder	11	8.25 10.25 12.25	10. 8. 6.	66-2/3
N. FK. SILVER CREEK Mixed sawtimber, well stocked, 160 yrs.	43.2	60	26.8 No pulp incl.	35.1 Incl. pulp removed of 7.9	Marked-to-leave seed trees	Chainsaw felling, jammer high lead	10	8.25 10.25 12.25 16.25+	10. 8. 6. 5.	66-2/3 75% pulp
INDIAN-HUNT Mixed sawtimber, well stocked, 200+ yrs., over mixed seedlings, poorly stocked.	31.0	20	21.3 Pulp incl.	19.2 Incl. pulp removed of 13.2	Clearcut with removal of pulp	Chainsaw felling, medium rubber-tired & crawler tractor skidder	10	8.25 10.25 12.25+	12. 10. 8.	50% & 66-2/3 75% pulp
JACK PINE FLATS Mixed sawtimber poorly stocked, 100 yrs., over mixed polesize, well stocked, 60 yrs.	50.0	0	3.0 Pulp incl.	8.7 Incl. pulp removed of 4.2	All overstory over 9" d.b.h. removed, incl. pulp	Chainsaw felling, small crawler (D-4) & small rubber-tired skidder	9	8.25 10.25 12.25+	10. 8. 6.	66-2/3 75% pulp

APPENDIX II

Table 11.--*Post-sale transect survey residue measurements results*

Sale name	Volume 3" dia. & larger			Weight 3" dia. & larger			Weight smaller than 3"			Pieces 3" dia. + any length			*Products					
	Total residue D & G	Green residue	Dead residue	Total	Rotten	Sound	Fine Fuels Total	0-1"	1-3"	Total	Sound	Unsound	SL	HL	CP	P	PB	SSB
	Ft³/acre			*tons/acre*						*pieces/acre*			*No./acre*					
Chilco	472	359	113	5.44	1.44	4.00	6.44	2.63	3.81	355	154	201	70	0	0	11	89	0
Lee Creek	3848	2329	1519	43.92	12.47	31.45	10.75	3.40	7.35	736	318	418	72	0	0	21	263	8
Danby Ridge	2411	1384	1027	25.57	13.61	11.96	11.82	1.95	9.87	492	190	302	20	0	0	0	155	4
N. Fk. Silver Cr.	2027	742	1285	21.36	11.06	10.57	11.80	3.02	8.78	635	347	288	54	0	0	15	155	8
Indian Hunt	3142	1365	1777	31.82	22.28	9.54	8.31	2.90	5.41	480	292	188	17	0	0	37	61	9
Jack Pine Flats	1817	663	1154	18.63	12.16	6.47	6.84	2.48	4.36	516	244	257	20	0	0	34	106	2

**Products - Priority Classification*

SL, Sawlog - 8'6" x 4" top or larger, all coniferous species
HL, Houselog - 8' to 12' x 9" top and straight, DF, WL, LPP, WRC
CP, Corral Pole - 8' to 20' x 3" top, DF, WL, LPP, WRC
P, Post - 6½' to 10' x 3" top or larger, DF, WL, LPP, WRC
PB, Pulp Bolt - 8' x 3" top or larger, all species except WRC
SSB, Shingle and Shake Bolt - 6'+ x 12" top or larger - WRC

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Chase, Alfred L.
1979. Salvaging logging residues in mixed-conifer stands of north Idaho. USDA For. Serv. Res. Pap. INT-225, 20 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Describes the condition and volumes of residues following conventional logging of two mixed conifer stands in north Idaho. Presents production rates and additional products recovered in relogging to more stringent than normal utilization standards.

Relogging of conventionally harvested stands offers possibilities for additional product recovery and debris reduction. Comparison of volumes of residue larger than 3-inch-diameter before and after logging showed a 44 percent reduction on one site and a 59 percent reduction on the other.

KEYWORDS: logging residues, salvage logging, logging practices, wood utilization.

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